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ANOMALOUS VISIBLE EMISSION OBSERVED FROM THE REAR SIDE OF LASER—ETC(U)

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ANOMALOUS VISIBLE EMISSION OBSERVED FROM THE REAR SIDE OF LASER-IRRADIATED THIN TRANSPARENT TARGETS

The study of the laser-pellet interaction in planar geometry on thin target foils or films allows access to the cold rear (inner) surface of the target for a variety of optical diagnostics. We have previously reported temporally and spectrally resolved visible emission measurements to determine the time history of the brightness temperature of this rear surface for thin opaque targets irradiated in vacuum.¹ These measurements were performed as part of an effort to understand the mechanisms that transmit energy through the laser-irradiated targets, which, in the context of the ablative implosion of spherical inertial confinement fusion targets, can result in deleterious preheat of the pellet fuel. However, for transparent targets such as CH, there is an ambiguity in the source of the visible light observed from the rear, since light emitted from the hot irradiated (front) surface of the target may be transmitted through the target and be confused with rear surface emission phenomena. A set of emission measurements on thin irradiated CH and glass targets is reported here that display a characteristic double-peaked temporal signature that has not been previously reported in this context. This is due to the formation, shortly after the initial front surface breakdown, of an optically thick layer intermediate between the front and rear surfaces of the thin film targets. This layer strongly attenuates the front surface emission, and is itself virtually nonluminous as seen from the rear, so that the heating of the rear surface may be unambiguously observed. Upon heating, the rear surface quickly becomes an optically thick plasma that behaves as a blackbody emitter, permitting rear surface time-resolved brightness temperature measurements to be made.

These measurements were performed at an incident laser irradiance of $5 \times 10^{12} \text{ W/cm}^2$ and a 1-mm spot size on large planar targets using the

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NRL Pharos II laser system, which provided up to 500 J in a 4-nsec FWHM, 1.05- μ m pulse. The rear surface luminosity was detected with a monochromator equipped with a fast (1-nsec) photomultiplier. Many CH target thicknesses were used, ranging from 2.5 to 30 μ m. For each target thickness, a small early light peak is observed from the rear of the target (see Fig. 1) which quickly decreases and whose amplitude and timing are independent of target thickness. This is followed by a second signal whose peak amplitude monotonically decreases and whose peak shifts later with increasing target thickness. Similar behavior is seen on thin glass targets, and the behavior of the second peak is similar to that observed on opaque Al targets of comparable areal density.

We conclude that the first signal is due to visible light emission from the front of the target that occurs at front surface breakdown, very early in the foot of the laser pulse at an irradiance of $\sim 10^{10}$ W/cm². Observation through the foil of the rapidly heating front surface ($T_{\text{peak}} > 200$ eV) is quickly masked by the formation of an opaque region between the front and rear surfaces. Streak photography of the emitted rear surface light (Fig. 2) shows that transmitted front surface luminosity cuts off rapidly within the laser focal spot, but persists at the periphery, where the hot front surface plasma plume expands laterally beyond the focal spot region. Within the focal spot, there is a time delay followed by rising visible emission characteristic of rear surface heating near the peak of the laser pulse. A similar double-peaked signal has been previously noted in the transmission of an irradiating laser beam through a transparent target.² In that case, transmission of the laser beam cuts off from the time of the front surface breakdown until laser burnthrough occurs. In our experiments, however, burnthrough does not occur, and to our knowledge the temporal emission sequence we describe here has not been previously reported.

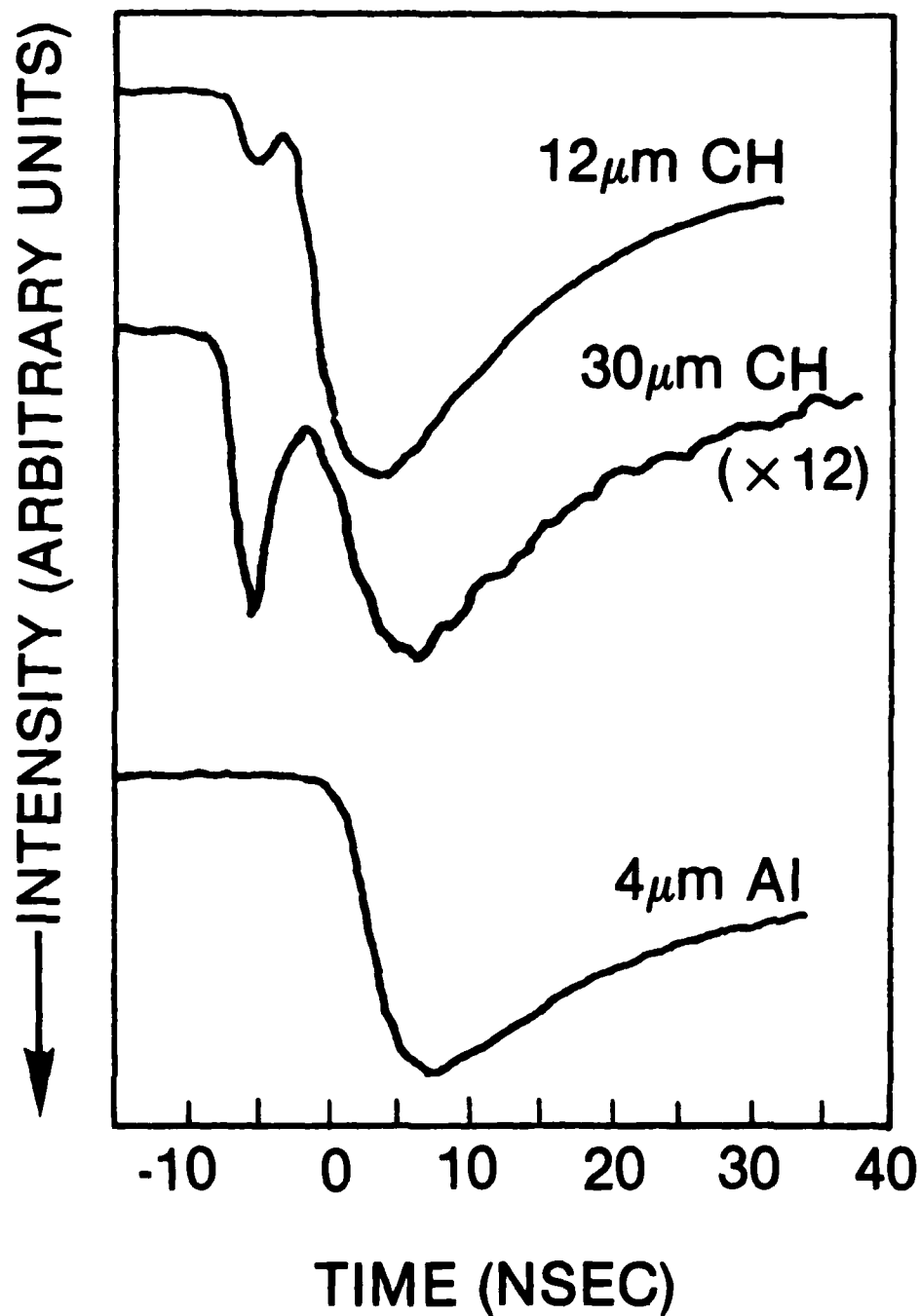
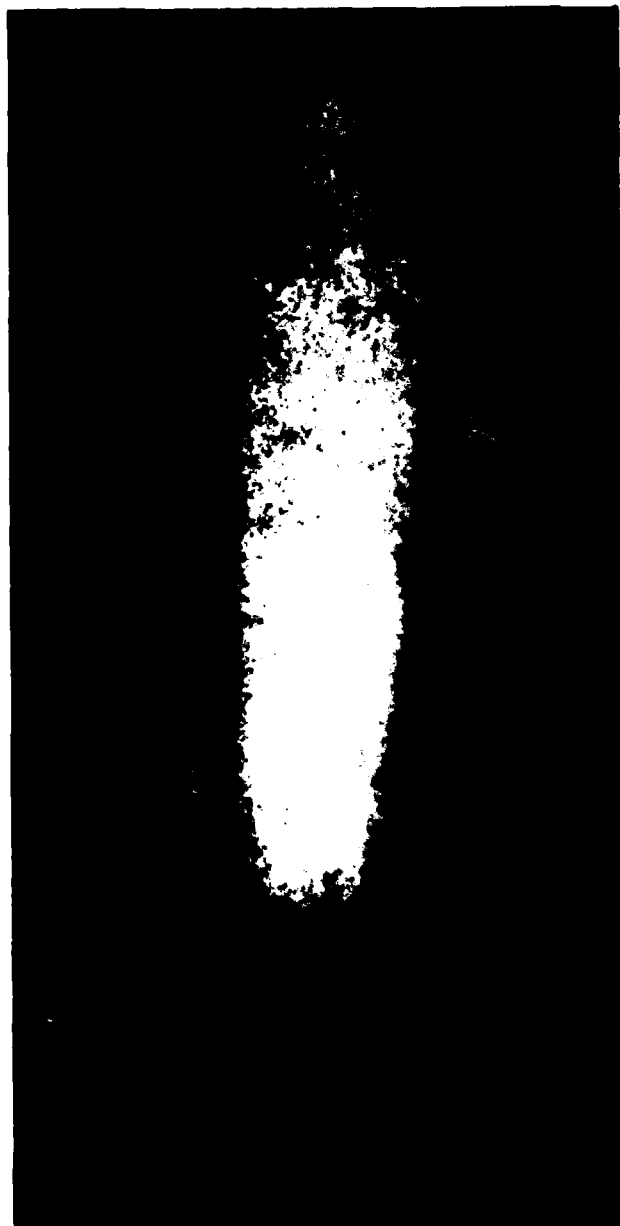
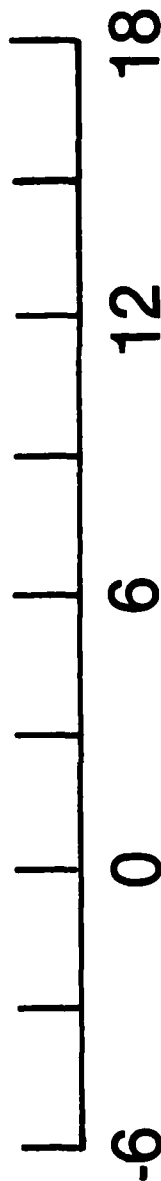


Fig. 1 — Rear surface luminosity measurements ($\lambda = 4717 \text{ \AA}$, $\Delta\lambda = 33 \text{ \AA}$) for two transparent targets, $12 \mu\text{m}$ CH and $30 \mu\text{m}$ CH, and an opaque $4 \mu\text{m}$ Al foil target, showing the additional early peak observed for the transparent targets. Time zero refers to the peak of the laser pulse.



1 mm



TIME (NSEC)

Fig. 2 — Streak photograph of rear surface visible emission ($\lambda = 5461 \text{ \AA}$, $\Delta\lambda = 100 \text{ \AA}$) for $7 \mu\text{m}$ CH foil target. (1 mm corresponds to the laser focal spot diameter.) The outer halo is due to front surface light emission from a plasma which is expanding laterally while light from the central plasma region stops being transmitted. The inner region is rear surface emission, beginning later in time.

Our observations are in contrast to those reported for impact shock experiments on solid transparent targets in vacuum³, in which shock luminosity is observed from the rear through the undisturbed portion of the transparent target to the emitting layer in the vicinity of the shock. In such cases, emission has been reported to rise suddenly as the shock is applied at the front surface, remain relatively flat while the shock is within the material, and then relax abruptly to a lower value characteristic of the residual, zero-pressure state when the shock reaches the rear surface. (The overtaking of the shock by a rarefaction wave can also cause an abrupt decrease in the observed emission.) In our long-pulse (4-nsec) laser acceleration experiments on thin targets, we avoid strong shock effects, and the observed rear surface heating is believed to be due primarily to other phenomena. Thus the transmission cutoff may be caused by the penetration of a temperature gradient into the target, whose leading edge is both cool enough (.5 eV) to be at most weakly luminous, and optically dense enough to obscure light emitted from hotter regions nearer to the front of the target. Shock-induced luminosity in transparent solids may be accompanied by loss of transparency, due to such effects as chemical breakdown, pressure-induced change to a semi-conductive or conductive state, loss of optical homogeneity, phase change, etc.⁴ Similar effects are presumably responsible for the opacity observed here. The continued transmission beyond the edge of the irradiated spot as shown in Fig. 2 would then be caused by insufficient bulk heating to cause transmission to cut off, and the intermediate dark layer would be caused by transmission cutoff coupled with insufficient rear surface heating to cause detectable emission.

On the basis of these observations, the second observed peak consists of visible emission from the rear surface behind the focal spot. When

the entire optical detection system is calibrated on an absolute scale, this rear surface luminosity can be directly related to absolute blackbody emission levels and rear surface temperatures thereby determined. The results of such a study on transparent targets will be reported in detail elsewhere.⁵

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